AD/A-000 447

THEORETICAL AND METHODOLOGICAL QUESTIONS OF SCIENTIFIC-TECHNOLOGICAL FORECASTING

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21 October 1974

UNCLASSIFIED
Security Classification

AD/A-000 447

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author)
Foreign Technology Division
Air Force Systems Command
U. S. Air Force

2a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

2b. GROUP

3 REPORT TITLE
THEORETICAL AND METHODOLOGICAL QUESTIONS OF SCIENTIFIC-TECHNOLOGICAL FORECASTING

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)
Translation

5 AUTHOR(S) (First name, middle initial, last name)
V. Lisichkin

6 REPORT DATE
1971

7a. TOTAL NO. OF PAGES
19

7b. NO. OF REFS
0

8a. CONTRACT OR GRANT NO.

b. PROJECT NO.

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)
FTD-HC-23-2334-74

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10 DISTRIBUTION STATEMENT
Approved for public release; distribution unlimited.

11 SUPPLEMENTARY NOTES

12 SPONSORING MILITARY ACTIVITY
Foreign Technology Division
Wright-Patterson AFB, Ohio

13 ABSTRACT
05

DD FORM 1 NOV 68 1473

UNCLASSIFIED
Security Classification

EDITED TRANSLATION

FTD-HC-23-2334-74 21 October 1974

THEORETICAL AND METHODOLOGICAL QUESTIONS OF SCIENTIFIC-TECHNOLOGICAL FORECASTING

By: V. Lisichkin

English pages: 14

Source: Sovet Ekonomicheskoy Vzaimopomoshchi. Postoyannaya Komissiya Po Koordinatsii Nauchnykh i Tekhnicheskikh Issledovaniy. Teoriya i Praktika Prognozirovaniya Razvitiya Nauki i Tekhniki v Stranakh-Chlenakh Sev, Izd vo Ekonomika, Moscow, 1971, pp. 46-53

Country of Origin: USSR
Translated under: F33657-72-D-0854
Requester: FTD/PDTA

PREPARED BY:

TRANSLATION DIVISION
FOREIGN TECHNOLOGY DIVISION
WP-AFB, OHIO.

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All figures, graphs, tables, equations, etc. merged into this translation were extracted from the best quality copy available.

U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

* ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

FOLLOWING ARE THE CORRESPONDING RUSSIAN AND ENGLISH

DESIGNATIONS OF THE TRIGONOMETRIC FUNCTIONS

Russian	English
sin	sin
cos	cos
tg	tan
ctg	cot
sec	sec
cosec	csc
sh	sinh
ch	cosh
th	tanh
cth	coth
sch	sech
csch	csch
arc sin	$\sin^{-1}$
arc cos	$\cos^{-1}$
arc tg	$\tan^{-1}$
arc ctg	$\cot^{-1}$
arc sec	$\sec^{-1}$
arc cosec	$\csc^{-1}$
arc sh	$\sinh^{-1}$
arc ch	$\cosh^{-1}$
arc th	$\tanh^{-1}$
arc cth	$\coth^{-1}$
arc sch	sech^{-1}
arc csch	csch^{-1}
rot	curl
lg	log

V. Lisichkin
(USSR)

THEORETICAL AND METHODOLOGICAL QUESTIONS OF SCIENTIFIC-TECHNOLOGICAL FORECASTING

The enormously intensifying tempo of scientific-technological and of social progress is producing particular requirements for the management of economic processes. The essence of these requirements consists in the fact that the society finds itself in need of establishing direction, regulation and planning in a preliminary developed and scientifically based system of forecasts. It is in this connection that prognostication is summed up - a scientific discipline - investigating the principle of the process of development of forecasts.

The structure of forecasts is determined by three basic points; by the logical structure of the process of the development of forecasts; by analysis and synthesis of the objectives of forecasting; by the choice of methods of forecasting, relating to the specific character of the objective.

We shall consider the substance of each of these problems. Formulating prognostics to be the scientific discipline of the principles of the development of forecasts and of methods of forecasting, it is possible to clearly indicate the specific character of the objective, methods and system of concepts of prognostics. This point of view must be developed by the consideration of the methodological problems of forecasting scientific-technological progress. One of the first tasks of a methodology is the analysis of original concepts and the systemization of various types of forecasts. In view of the necessity of the identification of various expressions as forecasts and the

differentiation of forecasts from predictions and prophecies and of plans and programs, the formulation of the concept "forecast" is built upon the introduction of a series of requirements.

Forecast - this is an expression, fixing in terms of some sort of language system an unobserved event, and satisfied by the following conditions:

At the moment of expression it must be impossible to unambiguously determine its factualness or falseness.

It must contain an indication of a closed spatial or time interval, in which the forecasted event will take place.

At the moment of expression there must exist a means of verification (the possibility of indicating such a means) of the method of forecast.

There must exist (be possible to indicate) a means of a priori appraisal of the probability of the forecasted event.

There must exist (be possible to indicate) a means of checking the accomplishment of the forecasted event.

The effectiveness of the organization of the developments of the forecasts of scientific-technological progress is in many ways determined by the presence of a logically well founded system of processing information in a form closest to the algorithmic form. The fundamental task, therefore, is the solution of the question of the structure of the process of the production of a forecast. By the full cycle of the production of a forecast is understood the three stage activity of a predictor, directed

toward the determination of the characteristics and parameters of the objective of the forecast at one of three levels of lead (near, medium, and far). In the full cycle there are three stages:

The retrospective stage. At this stage eight basic tasks must be solved: the more exact definition of the objectives of the forecast; the determination of factors having an influence of the objective; the analysis of development tendencies of the objective of the forecast; the determination and appraisal of factors stimulating or retarding the development of these or other tendencies; the analysis of emerging possibilities of the development of the objective and the selection of the most well founded variants, estimates of their significance; the accurate formulation of indices or parameters of the objective in total; the division of the objective into structural units and the determination of parameters or properties of every unit; the determination of the significances of both the objective in total and of its structural units in every fixed moment in the past; the creation of a hypothetical parametrical model of the objective of the forecast.

The diagnostic stage. The essence of the work at this stage is the addition of selected methods of forecasting to each of the separate structural units of objectives with subsequent synthesis and combination of derived forecasts.

The stage of the forecast is broken down into three phases: the single, the synthesis and the combination. The single phase is the production of that number of forecasts which has been determined at the stage of diagnosis. The phase of synthesis is included in the combination of the single forecasts strongly related to the joining of structural elements of the objective of the forecast to the structure of the objective; the combination

is the joining according to definite rules of the synthesized forecasts of various ranges and of forecasts of objectives, belonging by nature to different classes.

After the completion of all three phases the total balancing of the quantitative indices included in the complex forecast of the system with the data on the economic potential, of resources, of demographic potential, etc., is carried out. The purpose of such a balancing is the attainment of the fullest agreement of the enlarged indices of the development of the object of the forecast.

One of the major tasks of prognostication is the analysis of the objective and the development of means of its synthesis in the process of the production of the forecast. The objective of a scientific-technological forecast is usually related to a concrete situation. Therefore, inasmuch as the productivity of a compiled forecast is determined above all by the synthesis of the objective of the forecast, the task arises of presenting the scientific-technological situation in the form of the objective of the forecast organized in a definite way. The latter may be done if a range of factors are determined, determining a given situation. For this goal a particular stage is employed, in the process of which the objectives of the forecast will also be synthesized: it has received the title of the stage of composition of the scenario.

Under scenario in the practice of social-economic, scientific-technological forecasting is implied the survey of a situation, inside of which concrete processes take place - the objectives of a forecast. This data is related to the most various sides of a forecasted scientific-technological social and economic situation and includes within itself the descriptions of separate factors and events exerting a direct or indirect influence on the realization of a concrete event - of the objective of the production of a forecast.

The composition of a scenario precedes the composition of a forecast. The task which is solved at the stage of the composition of a scenario is the discernment of an arrangement, in which the forecasting process is unfolded, with the purpose of separating in this arrangement elements which can show a definite influence on the event - the objective of the production of the forecast, and to establish the relationship acting between them.

The composition of a scenario must begin with the development of relatively simple indices of the situation, so that they may be transferred later to indices with more complex and more specific meanings in relationship to the given situation. The means of correcting complicated indices of the situation or of complicated operational units of the description is the analysis of the character of their relationships from the simple, or, put another way, the analysis of the character of the actualization of simple operational units of the description in relationship to the complicated.

The content of the scenario is characterized very much by a complicated structure. Its completeness in the informational plan is guaranteed with difficulty, therefore, in composing the scenario by questions of grouping informational material, it is necessary to impart great significance. Scenarios must be easily formed and useful both for operational utilization and for rapid modernization.

The means of synthesis of an objective for the production of a forecast within the framework of morphological analysis is a particular matrix, the lines of which correspond to the parameters of the objective, each represented through an aggregate of differential indices assumed as elementary.[1] Alternative variants on the basis of such a matrix, are derived from formal methods of joining by a broken line differential indices in separate lines.

If the solution of the problems of forecasting are related to the appraisal of changes in the learning of several areas, a prognosis is rendered before the necessity of processing on the basis of the present aggregate of information related to this area, an economic alphabet which may be effectively used for the description of processes uncovered in the present subject area, and for the tracing of an aggregate of tendencies in this area characterizing the modifications of the parameters. The construction of a thesaurus is another effective method for the solution of this task, found in practical application.

The fundamental function of the production stage of a forecast is the definition of alternative modifications of the system of differential traits and of its elements on the basis of the development of information on past and present events. In spite of the complete diversity of possibilities existing here, the set of method instruments applicable in developing information (with the purpose of obtaining investigative forecasts) is intended either for constructing extrapolations or for defining the influence of a factor on an event.

The establishment of a typology of curves representative of a tendency, and of the interpretation of forms of correlated curves in the content field, is an essential element of the analysis of the possibilities of extrapolated models. In the process of such an analysis facts are considered determining the curve of the growth of a parameter up to its ultimate meaning, and appraising their influence on the form of the corresponding curve. The consideration of all of these problematics is interrelated with the determination of criteria which must satisfy parameters, representationally reflecting the dynamics of the objective. Therefore, needs determine parameters, by which it is possible to carry out an extrapolation on the basis of the construction of so-called

envelope curves and reasons are being established for the increase of the accuracy of forecasts on the basis of extrapolation by envelope curves. The effectiveness of this method may be illustrated by the forecast of parameters of the speed and volume of the memory banks of computers.

For carrying out of the most accurate forecasts it is necessary to use a mathematical apparatus, permitting the appraisal of both a forecasting value and the probability characteristics of it. The methods of the theory of probability and of mathematical statistics, as well as the theory of Markovskii circuits are totally effective for this purpose.

The essential task of the development of information at the stage of carrying out a forecast is not only the carrying out of an extrapolation, but also the resolution of the task of appraising the influence of the related or nonrelated factors (R_j) on the value of the parameter (S^k). The relative influence of (R_j) on S^k may be appraised by means of juxtaposed expert comparisons, determining in every pair the most forceful factor. By this set of comparisons it is possible to place these juxtapositions into the corresponding matrix (a_{ij}) in which the predominance of the i factor under the influence of the j factor is designated by the unit standing at the intersection of the i line and the j column; the return direction of influence may be designated by a zero.

The most complex matrix of juxtaposition is derived if the force of the influence of every factor is presented in the form of a chance value, distributed on the basis of a definite law (for instance, the normal law). The program, developed for the computer, permits the derivation of necessary ranges for instances when the number of factors does not exceed 40.

The specifics of the above considered methods of the development of information at the stage of carrying out a forecast consist of that which plays a leading role only for the construction of forecasts of the research type.

For the normative forecasting of a determined goal and the task of a prognosis it is necessary to reconstruct the combination of elements distributed in space and time, guaranteeing by optimal samples the accomplishment of the set goal. This task is equivalent to the task of constructing a heuristic system, which will both demonstrate the model of the process of accomplishing the set goal and which will answer the conditions:

The set goal is a unit of the highest level of a system.

For the accomplishment of the goals an optimal variant of the structure of the system is selected.

Finding himself before the necessity of determining, proceeding from these premises, elements of the process of accomplishing the goals, the forecaster solves the converse task, he makes a retrospective forecast. Obviously, in this there is also included that reason that the forecast in the present instance must be attached to the model, approximating the forecasting process by means of a goal-tree.

Goals, ideas, concepts of research systems are identified and the necessities and technological capacities for their development ranging from separate components and functional subsystems to the system as a whole are established.

Criteria are formulated and weighted coefficients are determined, necessary for the apparisal of tasks at every level of the "tree" as a whole.

Weighted coefficients for every element of the "goal-tree" at every level of the "tree" are determined.

The construction of a "goal-tree" in the above indicated manner assumes: the presence of forecasts of the development of science and technology; a scenario of the situation, in the framework of which set goals are solved; related political, economic programs and concepts; agreed upon criteria for the determination of numerical values, established at the third stage.

The "goal-tree" is the structural basis for modeling a forecasting situation. In the process of constructing a model not only the weighted coefficients of these or those elements of the "goal-tree" are determined, but the most complex characteristics of the significance of separate elements are also determined. Therefore, the determination of corresponding values presumes the utilization of a corresponding mathematical apparatus, in particular the combination of elements connected with a concrete graph of the "goal-tree". Thereby particular attention is paid to those questions, such as the accuracy of the evaluation of the contribution of a factor in the widest occurrence; the comparison of qualitatively varied objectives, the synthesis of a general combination of the graph with the particular combinations of the levels.

Besides the methods of forecasting with the utilization of the "goal-tree", in practice a reflection of the method of forecasting on the basis of matrix representations of interconnections between various branches of science and technology has also been found. The matrix, rows and columns, appear in conditions where the basic direction of the growth of science and technology is already determined to be an effective means for the development of narrow areas of the scientific research front

and also of the most interesting (in the plan of material output) sections of that front.

The development of the problem of logical analysis and heuristic deductions as an instrument of forecasting has great significance. The specific character and diversity of objectives of forecasting, not excluding the specific community active in forecasting, is dependent upon the very nature of the research process. As a type of scientific research forecasting at all stages is based upon logical analysis and heuristic deductions. This circumstance is not accepted in the opinion of many researchers who usually oppose or react to various classes of logical method (inductive, deductive, or conclusion by analogy) and methods based upon heuristic expert appraisal (D. Bright, E. Jansch, M. Setron). This means that the appropriateness of using these two groups of methods to the forecasting of every objective provides the basis for the inclusion of them into a unified class of forecasting methods. This class includes in itself conclusions by induction, deduction and analysis by analogy, synthesis, observation and experiment, advancement of suppositions and hypotheses, classification and systemization, methods of expert appraisal and the collective generalization of ideas, the synthesis of Delphic and Pertovsky technology, etc.

The effectiveness of the utilization of logical means and heuristic deductions for forecasting is in many instances related to clearly formulated limitations and the principles of application. The non-observance of these requirements both by domestic and foreign scientists repeatedly occurred and led to erroneous forecasts. In the capacity of a criterion for the reliability of a forecast, derived, for example, on the basis of conclusions by analogy, it is possible to assume a hierarchy of logical

conclusions (among them causal analogies) developed by A. Uemov.

The normative character of many forecasting tasks supposes the investigation of a goal event, as final, demanding for its realization the accomplishment of a series of intermediate developments, linked together in a net. The derivation of these events is the foundation for the final event, the apparent probability of which may be evaluated by the inquiry of experts. Therefore, the forecast of the feasability of the final development is related to the appraisal of the time of realization of intermediary developments. The task is solved by the method of expert appraisal. Besides this, the definitive forecast presumes the clarification of the question of the influence of the sequence of intermediate events on the final (event). It is possible to derive this answer by using the critical path method. The integration of these two methods permits normative forecasts to be considered as a Petrovsky net, the nodes of which correspond to events, revealed by experts, for which the determination of the time of realization must be defined.

Use of the Delphic technique (O. Helmer, T. Gordon) for forecasting of scientific-technological development must provide for a series of requirements. The basic ones are:

Clear formulation of questions of inquiry and the necessity of answers in quantitative form; the presence of several rounds of inquiry with an optimum time (a number of months) between them; the stability and optimum number of groups of experts.

Without the fulfillment of these requirements it is difficult to approach a convergence of expert opinions, the exclusion of the influence of background information, coming to the experts through return communication channels, and in the final analysis the derivation of unmistaken forecasts.

Existing methods of expert opinions for all positive qualities possess one essential inadequacy: the lack of a method of separating objective and sub-objective motives in the opinion of the expert. This leads to a systematic mistake in the forecasts, the source of which lies in the peculiarities of the conceptual structure of the thinking of the experts. For the exclusion of such mistakes definite possibilities are revealed by the analysis of the conceptual structure of thought on the basis of a method of semantic differentiation (Ch. Osgood, D. Blok, G. Kumata, G. Triandis). It is possible to anticipate the derivation of data on the connections of various types of the conceptual structure of thought and to determine the types of mistakes, permitted by the experts for concrete forecasts and opinions, which in their own turn serve as a basic method for the selection and evaluation of experts for the manning of expert brigades.

The process of forecasting on the basis of expert opinion is possible not only on the basis of individual inquiry (O. Helmer, S. Sherwin, T. Gordon), but also by the method of collective generalization of ideas. The effectiveness of the latter is characterized by the presence of non-trivial forecasts, which are difficult to derive by means of simple extrapolations. However, the process of the generalization of ideas must be strictly organized according to the following principles: criticism of expression is not permitted; the appraisal of proposals is accomlished later; unusual ideas are stimulated; a large quantity of advanced ideas are necessary; the combination and improvement of advanced ideas is necessary. This method, in particular, must be recommended for three types of tasks: the determination of a circle of alternative variations of the forecasting process; the selection of instrumentation for the production of concrete forecasts; the composition of scenarios.

The problem of the systemization and appraisal of methods of forecasting emerges as one of the central problems of forecasting. Methods of forecasting existing at the present time are extremely diverse in the area of application and are not equivalent in terms of accuracy and time lead. For the development of practical recommendations for the application of this or that method of forecasting it is necessary to conduct a comparative analysis, the effectiveness of which is related to the solution of the task of the classification of methods.

The formation of classes and sub-classes of methods of forecasting is important not only for their individual appraisal, but also for further synthesis or complexing. This circumstance is dependent on the fact that the objective of scientific-technological forecasting, as a rule, is a complex system with multiple interrelationships with different systems. Therefore, the task of complexing methods of forecasting is interwoven both with the differentiation of methods according to groups oriented toward the objective, and with the integration of individual methods ranked according to accuracy and time lead.

The effectiveness of the use of methods of forecasting and of forecasting appraisals in the practice of national economic planning is related to the solution of the questions indicated within the framework of a new area of scientific knowledge - forecasting.

Footnotes

page 48:

1. The idea of equilibrium of G. M. Dobrov.
2. The analogy of the mechanism of distinction of a prognostic situation and the mechanism of distinction of visual forms presented by A. N. Anisimov.

page 49:

1. F. Zwicki is the author of the morphological analysis in forecasting, using it for the synthesis of objectives of a forecast of flying machines.
2. By the Soviet forecasters G. M. Dobrov, B. G. Gmoshinsky, V. I. Obukhov and others that are developing a thesaurus for the narrow branches of technology.
3. The present method received a high appraisal for its use in the forecasting of parameters of technological systems. The (American) forecaster R. Ayres is its author.

page 51:

1. Representative system in this relationship: PATTERN, PROFILE and the method of dé l' Etoile.
2. QUEST, SCORE and others are systems exemplifying such methods.

page 53:

1. The formulation of the basic principles of the collective generation of ideas is connected with the name of B. Osborn. The practice of the application of a method by a number of U. S. firms permitted the refining of methodological procedures, and led to the increase of its effectiveness. In the USSR the present method is being developed by D. Iordansky.